

REMARKS/ARGUMENTS

Claims 1, 3, and 5-52 are pending.

Claim 1 has been amended.

Claims 2, 4, and 9 have been cancelled.

Claims 50-52 has been added.

Support for the amendments is found in the claims and specification (e.g., page 32, 43-45, and 48, and the Examples), as originally filed. Specially, claim 1 comprises the limitations of claim 9.

No new matter is believed to have been added.

The claims are rejected under 35 U.S.C. 103(a) (a) over Hibino et al., *J. Chem. Soc. Faraday Trans.*, 91:1955-59 (1995) and Chandran et al., US 2002/0003085 as evidenced by Arai et al., US 6,322,910, and (b) Hibino et al., Chandran et al., Arai et al., and Diekmann et al., US 6,268,076. The rejections are traversed because the combination of the references does not describe or suggest:

(i) micro-region reaction sites,

(ii) a working electrode layer to manage oxidation-reduction reactions is formed in the upper part of the cathode, and the micro reaction regions of nanometers to a micrometer in size where the oxidation-reduction reactions take place are introduced into the working electrode layer, and the claimed working temperature is 400-700 °C (or less than 700 °C)

(iii) applied current from 5 mA to 1A or an applied voltage is from 0.5 V to 2.5 V (as in claim 50),

(iv) a chemical reaction system which can decompose 50% of NO_x at the current density of 31 mA/cm² or less (as in claim 51), and

(v) the barrier of Diekmann et al. is different and performs a different function compared to the claimed barrier.

The claimed chemical reaction system efficiently excludes nitrogen oxides from exhaust gas containing oxygen. The system has micro reaction regions for performing oxidation and reduction reactions on a target substance introduced into a part of the chemical reaction so that oxygen and nitrogen oxides are separated and adsorbed from an exhaust gas within the micro reaction regions, thus allowing a target substance to be efficiently processed with low electric power consumption (see page 1 of the present specification).

Rejection (a).

The Hibino et al. electrochemical cell has a simple cell structure in which a zirconia electrolyte is sandwiched between an anode and a cathode of palladium. Therefore, substantial power is consumed by pumping oxygen that coexists in a gas to be treated.

As illustrated in Fig. 3, the cell must be supplied with a *large current*, e.g., as much as 500 mA/cm², for even decomposing 50% of NO_x.

Also, the claimed working temperature is 400-700 °C (or 400 °C to less than 700 °C) (e.g., as in the Examples of the present specification), while Hibino et al. describe that a temperature above 700 °C is required for the operation of the reactor because its large dc resistance and overpotential (page 1955, left col., second paragraph).

The claimed chemical reactor system provides a selective decomposition reaction of NO_x molecules in coexisting oxygen by introducing nanoscale “micro-region reaction sites” for solving problems described in the present specification (e.g., does not require an excessive energy consumption) (see pages 3-10). The “micro reaction regions” is a structure having an interface comprising the three metal phases, an oxygen deficient part, and micro spaces (see claim 1, element (2)).

With regard to known electrochemical cells for NO decomposition, including the cell of Hibino et al., Bredikhin et al., Inonics, DOI 10.1007/s11581-008-0249-5 (2008), (submitted with this paper) describe that *without* coexisting oxygen, the decomposition was

known in a cell having a structure Cathode/YSZ/Anode (as in Hibino et al.) and the decomposition of NO takes place only when all oxygen is pumped away from the near electrode area (see pages 2-3, "Traditional type of electrochemical cells for NO decomposition"). Further, all known cathode materials used up to now for electrochemical reduction of NO show a low selectivity for NO reduction in the presence of the excess oxygen and cannot be used for practical applications (page 3, right col., last paragraph). Bredikhin et al. further describes disadvantages of previously known electrochemical cells (pages 2-3). *See also* Hamamoto et al., J. Ceramic Society of Japan, Supp., 112-1 PacRim5 Special Issue, 112(5):S1071-1074 (2004), and Aronin et al., J. Am. Ceram. Soc., 88(5):1180-1185 (2005) describing disadvantages of known cells and advantages of the claimed cell (submitted with this paper).

The Examiner has alleged that in the Hibino et al. cell, boundaries between YSZ and a cathode/anode have a metal phase of Pd electrode and some gaps formed between small particle grains. However, the Hibino et al. Pd electrodes do not comprise "an interface" comprising the metal phase and gaps because the Hibino et al. electrodes are made of Pd and, therefore, the entire Pd electrodes are "a metal phase and gaps".

The Examiner has agreed that the Hibino et al. cell does not comprise a working electrode layer and relied on Chandran et al. describing an additional Pt coating on a LMS electrode (page 1, [0010]) interpreted by the Examiner as "a working layer."

The purpose in Chandran is to form other cathodes on a cathode, in an electrochemical cell for "increasing oxygen concentration" by oxygen pumping.

A conductive porous layer 54 of Pt is formed on the cathode 52 of Fig. 3. This structure enhances permeability of the gas to be treated because of porosity, and reduces the voltage drop by suppressing resistance because of the high conductivity of a Pt cathode (see page 3).

By contrast, the “micro-reaction regions” in the claimed reaction system are micro-reaction regions where oxidation-reduction reactions of a target substance take place, and interfaces consist of a metal phase - an oxygen deficient part - micro spaces at the points of contact between the electron conduction phase and the ion conduction phase (see claim 1). The micro-reaction regions are introduced into the cathode (see claim 3) and have a size of from a nanometer to a micrometer scale (see claim 1).

Therefore, even in the Hibino et al. single cell is supplemented with Chandran et al.’s overlapping cathodes, the combined structure provides an oxygen enrichment, while the claimed structure provides a selective decomposition of NO_x.

Also, the claimed micro-reaction regions comprise a metal phase, an oxygen deficient part and micro spaces that provide NO_x selective reaction sites, while the Chandran et al. structure adds a conductive porous electrode that provides an oxygen enrichment.

The effect of a selective reaction of NO_x in coexisting oxygen, which is the point of the invention of the present application, is the exact opposite of the purpose of the cathodes according to Chandran et al. providing an oxygen enrichment.

Thus, Chandran et al.’s cathode cannot accomplish the goal (promoting a reaction) of the claimed reaction system.

Accordingly, the combined system of Hibino et al. and Chandran et al. AND the “micro regions”, oxygen-deficient parts, nanoparticles and gaps coexisting at a nanoscale of the claimed reaction system are different. Oxygen-deficient parts, nanoparticles and gaps coexist at a nanoscale are essential for the selective decomposition reaction of NO_x as micro-region reaction sites.

Moreover, the Examiner provides inconsistent arguments with regard to a combination of Hibino et al. and Chandran et al. because:

(1) The claimed system comprises (i) interfaces consisting of a metal phase of the electron conduction phase, an oxygen deficient part of the ion conduction phase and micro spaces (gaps) surrounding the contact points, wherein the interfaces are formed as micro reaction regions, and (ii) a working electrode layer formed in the upper part of the cathode, wherein the micro reaction regions are introduced into the working layer.

(2) According to the Examiner, the Hibino et al. Pd electrode has a metal phase and gaps. The Examiner also stated that Hibino et al. do not describe the working layer. Thus, it appears that the Examiner's opinion is that Hibino et al. describe a metal phase and gaps but they are not located in the working layer. However, the metal phase and gaps of the claimed system are a part of the micro regions, wherein the micro regions are a part of the working layer as in claim 1.

Further, even if we assume for the sake of argument that the Chandran et al. additional Pt coating (defined by the Examiner as a working layer) comprises a metal phase and gaps, the Pt coating is not forming an "interface" with an ion conduction phase but is disposed on the top of the Pd electrode which is in contact with the ion conduction phase.

In the claimed system, "the area including gap" is located within cathode, i.e., in the layer 2 of Figure 1.

In addition, the Examiner has asserted that the Chandran et al. cell is fully capable of reducing NO_x (the goal of the claimed reaction system) (see page 3 of the Official Action). Applicants respectfully disagree.

Chandran et al. cell is for pumping oxygen which is capable of reducing NO_x in the side of cathode. It is well known that NO_x can be reduced at reducing side of an electrode of the electrochemical reaction cell by the teachings of Pancharatnam et al., J. Electrochem. Soc. 122, 869 (1975) (see also Bredikhin et al., Inonics, DOI 10.1007/s11581-008-0249-5 (2008),

submitted with this paper describing shortcomings of the Pancharatnam et al. cell on page 2, right col.).

In the claimed system, a selective reduction of NO_x under the condition of the *co-existence of oxygen* can be accomplished firstly by forming micro reaction space.

Under the condition that there is no co-existence of oxygen (as in Pancharatnam et al. and Hibino et al.), any electrochemical cell is capable of reducing NO_x.

Also, the Examiner has alleged that Arai et al. describe “an oxygen deficient layer” laminated under a layer which is laminated with the addition of oxygen (col. 4, lines 55-65). The Examiner has asserted that because the Hibino et al. Pd electrodes are attached to YSZ by electroless plating without the addition of oxygen at 90 °C, an oxygen deficient layer is inherently formed at the boundary of Pd electrodes and YSZ (pages 5-6 of the Official Action). However, the entire Pd electrodes of Hibino et al. are “the oxygen deficient”, because the entire Pd electrodes (not just a layer) are produced under the conditions identified by the Examiner as “oxygen deficient.” Further, in the claimed system, the working layer comprises the oxygen deficient part, while, according to the Examiner, the Hibino et al. Pd electrodes comprise “an oxygen deficient layer” and the Hibino et al. cell does not comprise “a working layer.”

The Examiner’s arguments with regard to combining Hibino et al., Chandran et al., and Arai et al. are inconsistent.

Also, the Hibino et al. cell must be supplied with a large current, e.g., as much as 500 mA/cm² for decomposing 50% of NO_x (fig. 3), while the claimed cell requires 31 mA/cm² or less for decomposing 50% of NO_x, as demonstrated in the Examples of the present specification. The Hibino et al. cell is not capable of decomposing NO_x at such low current density.

Thus, Hibino et al., Chandran et al., and Arai et al. do not make the claimed system obvious. Applicants request that the rejection be withdrawn.

Rejection (b).

The Examiner has alleged that functions of the Diekmann et al. barrier layer and the claimed barrier layer are the same (pages 8-9 of the OA).

In response, it is noted that the purpose of the barrier layer of the Diekmann et al. is opposite to that of claimed barrier layer, and, therefore, the Diekmann et al. is not capable of performing the function of the claimed barrier layer.

Further, Diekmann et al.'s barrier layer is capable of providing a chemical reaction in the side of cathode, while the present system is capable of reducing NO_x selectively under the co-existence of oxygen.

More specifically, the Examiner has indicated that "[h]owever, Diekmann disclose a current collector for solid oxide full cell. The reference Diekmann states that a barrier layer is added to the cathode side to vanishingly low electric conductivity, ensuring enough electrical current between cathode and anode for electrochemical reaction (col. 2, lines 5-12)" (paragraph 31, pages 8-9 of the Office Action). Applicants respectfully disagree.

Diekmann et al. describe that "[f]or this reason (i.e., the cathode in particular becomes damaged by volatilization of chromium oxides), the prior art provides for coating the cathode side with a special full-surface barrier layer, of LaCrO₃, for example, in order to prevent volatilization of the chromium oxides. It is also known from the prior art that, by addition of aluminum, the alloy forms a cover layer of Al₂O₃. This cover layer in turn is more stable than the chromium oxide cover layer, but the cover layer of Al₂O₃ has only vanishingly low electrical conductivity." Col. 1, line 65 to col. 2, line 7.

The disclosure of col. 1-2 of Diekmann et al. cited in the previous paragraph only shows that in order to prevent volatilization of the chromium oxides, by addition of

aluminum, the alloy forms a cover layer of Al_2O_3 , that this cover layer is more stable than the chromium oxide cover layer, and that the cover layer of Al_2O_3 , has only vanishingly low electrical conductivity.

Thus, the acknowledgement of the facts disclosed in Diekmann et al. on pages 8-9 of the Office Action is not correct.

With regard to the claimed barrier layer, the barrier layer has a material and structure, which prevent a supply of electrons necessary for producing oxygen ions when oxygen molecules have been absorbed into a surface, and inhibit electrons supplied by the chemical reaction part and particularly the reduction phase from arriving at the surface, and the barrier layer is preferably an ion conductor, mixed electrical conductor or insulator (see lines 12-22, at page 16 of the description of the present application).

The barrier layer of Diekmann et al. is used to prevent volatilization of the chromium oxides of the current collector or interconnector.

Therefore, Diekmann et al. do not describe or suggest what Applicants have discovered that include a barrier in order to prevent a supply of electrons necessary for producing oxygen ions when oxygen molecules have been absorbed into a surface, and inhibit electrons supplied by the chemical reaction part and, particularly, the reduction phase from arriving at the surface.

Thus, Hibino et al., Chandran et al., Arai et al., and Diekmann et al. do not make the claimed system obvious. Applicants request that the rejections be withdrawn.

Claims 41 and 47 are rejected under 35 U.S.C. 112, second paragraph for lack of antecedent basis. Applicants respectfully traverse because Claim 1 recites an ion conduction phase, a reduction phase, and anode an oxidation phase. However, to further clarify the invention, claim 1 has been amended. Applicants believe that claims 41 and 47 are clear.

Applicants request that the rejection be withdrawn.

A Notice of Allowance for all pending claims is requested.

Respectfully submitted,

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